# Status of Whitebark Pine and Other High-elevation Five-Needle Pines with Emphasis on Pacific Coast Ecosystems: What are the Issues and Concerns? Perspective from California

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## Abstract

Six of nine five-needle white pine species native to the U.S. are found in California, and all of these are susceptible to the exotic pathogen, white pine blister rust (*Cronartium ribicola*). Since entering California, the rust has spread south over the geographic range of sugar pine, but until recently little was known about its impact on the higher elevation pines. From 1995 to 1999, a survey of five species in Sequoia and Kings Canyon National Parks revealed rust in plots of sugar and western white pine only. In 2004-2005 a survey of the high elevation species over their California ranges revealed rust in plots of western white pine, whitebark, and the northern foxtail populations, but not in limber, southern foxtail, or Great Basin bristlecone pines. Mean incidence of rust across all plots was relatively low (12 to 15%), but variation among plots was high (0 to 92%). Rust was observed in a plot at 3400 m elevation in the southern Sierra. Other stress factors such as mountain pine beetle, fire exclusion and climate change are discussed in relation to their impacts on these pines. Practical issues for future management of these high-elevation pines and their ecosystems are also presented.

## Introduction

Six of nine five-needle white pine species native to the U.S. are found in California. They are sugar pine (*Pinus lambertiana*), western white pine (*P. monticola*), whitebark pine (*P. albicaulis*), limber pine (*P. flexilis*), foxtail pine (*P. balfouriana*), and Great Basin bristlecone pine (*P. longaeva*). The six species range in elevation from about 150 to 3700 meters. In the State, sugar pine grows at low to mid elevations, western white pine at mid- to high elevations and the remaining four species at high elevations where they are adapted to harsh mountain environments, provide habitat to wildlife, and are culturally valued for their aesthetic appearance and longevity. All are critical components of their ecosystems. However, both biotic and abiotic factors may be affecting the health of these trees and associated ecological components. White pine blister rust, mountain pine beetle, fire exclusion, and changes in climate are most often mentioned in the literature as affecting high elevation pines elsewhere in the West and are discussed in relation to California.

## White Pine Blister Rust

One significant biotic factor is the exotic fungal pathogen, white pine blister rust (*Cronartium ribicola*). The pathogen has had a severe impact on five-needle pines in the western U.S., particularly the northwestern States and the western Canadian provinces (Samman et al. 2003, Schwandt 2006). Moreover, it continues to spread over the geographic distribution of these pines. In California, the rust's migration from the north has led to serious concern over its impact on the health of these species and their ecosystems.

**Chronology of the spread of white pine blister rust in California:** The history and current distribution of blister rust on the lower elevation sugar pine is well-documented. The species is a significant source of rust inoculum due to it wide distribution in the State. The pathogen first entered California about 1930 (Shelly Creek, Grants Pass-Crescent City highway), spread steadily south on sugar pine, and within 70 years had reached Breckenridge Mountain at the southern Sierra Nevada (Kliejunas and Adams 2003). White pine blister rust has not yet stabilized on sugar pine, and continues to spread and intensify. Sugar pine in the Tehachapi Mountains and southern California remain uninfected. Until recently, the incidence and impact of the rust in high elevation ecosystems in California were largely unknown. The rust was reported on foxtail pine in the Klamath Mountains in 1967. Reports since then suggest that the rust may just be entering the higher elevations.

**Surveys of white pine blister rust on high-elevation five-needle pines:** An extensive survey of sugar, western white, whitebark, limber, and foxtail pines in Sequoia and Kings Canyon National Parks was performed from 1995 through 1999 (Duriscoe and Duriscoe 2002). A total of 151 permanent monitoring plots were established. Rust was found only in plots with sugar pine (21% average incidence) and western white pine (3% average incidence). The populations of whitebark, limber, and foxtail pines within the plots were not infected by the rust.[1] Incidence and severity of rust was closely associated with elevation: it was rarely found above 2,700 meters, and it was most often found in valley bottoms.

A field project was initiated in 2004 to gather blister rust information on high elevation five-needle white pines in other areas of the State. The objectives were to 1) determine the current incidence and levels of blister rust associated with western white, whitebark, limber, foxtail, and bristlecone pines in California, and 2) to establish a system of permanent plots for long-term monitoring of rust incidence and severity in these pine species. A total of 118 long term monitoring plots were established over two field seasons; 43 in western white, 44 in whitebark, 14 in limber, 12 in foxtail, and 5 in Great Basin bristlecone. Standard plot and tree data were collected as well as information on *Ribes* spp. (the alternate host), white pine blister rust, mountain pine beetle, and other damaging agents.

Rust was present in western white (25 of 43 plots), whitebark (18 of 44 plots), and the northern populations of foxtail (5 of 6 plots). It was not found in limber, Great Basin bristlecone, or the southern populations of foxtail pine (Table 1). Non-aecial evidence of rust

[1] Rust was noted on one foxtail pine in SEKI by a forest pathologist, but that observation was not part of the SEKI survey.

was noted on six trees in one northern and on two trees in one southern foxtail plot.[2] The mean rust levels were relatively low across plots (12 to 14%), but varied widely from plot to plot (0 to 90%). Moderate incidence was observed in northwest California, north-central Sierra Nevada, and the west side of the southern Sierra Nevada. The absence of rust in limber, the southern populations of foxtail[2], and Great Basin bristlecone pines may be due mainly to the time factor; the rust pathogen has been present in the southern Sierra (on sugar pine) only since the 1960s. With more time and the continuous nature of the forests, rust on sugar pine and western white pine at lower elevations will provide an inoculum source for *Ribes* spp. and, in turn, inoculum for the higher elevation whitebark, foxtail, and limber pine. In this survey, rust was observed on whitebark pine at about 3400 m. Rust is spreading not only south in latitude, but also upward in elevation.

## Mountain Pine Beetle

Another biotic factor affecting high-elevation five-needle pines is the mountain pine beetle (*Dendroctonus ponderosae*). A native to western North America, mountain pine beetle has several main host species, i.e., ponderosa, lodgepole, sugar, and western white pines, but may attack other five-needle pines as well (Gene et al. 1990). In California, the biology of mountain pine beetle is not well-understood for the high-elevation forests. In our survey, beetle activity was present in about 50% of the plots in western white, whitebark, and the northern population of foxtail, but absent from the plots of limber, the southern populations of foxtail, and Great Basin bristlecone pines (Table 1). Overall, mortality levels on the plots were low. Mortality ranged from zero in limber pine to a mean of 4% in western white (Table 1).

Table 1. Incidence of blister rust, mountain pine beetle (MPB) and mortality levels in 118 monitoring plots in California.

| Pine Species | No. Plots with Rust | Avg. % Rust Levels (Range) | % of Plots with MPB | % Mortality (Range) |
|---|---|---|---|---|
| *P. monticola* | 25/43 | 14 (0 – 90) | 53.5 | 4 (0 – 49) |
| *P. albicaulis* | 18/44 | 13 (0 – 76) | 62 | 1 (0 – 12) |
| *P. flexilis* | 0/14 | 0 | 0 | 0 |
| *P. balfouriana* N | 5/6 | 12 (2 – 32) | 42.8 | 1 (0 – 6) |
| *P. balfouriana* S | 0/6 | 0 | 0 | 1.5 (0 – 9) |
| *P. longaeva* | 0/5 | 0 | 0 | 0 (0) |

## Fire Exclusion and Climate Effects on High-Elevation Five-Needle Pines

California's forests have been substantially modified by wildland fire suppression since the early 20$^{th}$ century (McKelvey et al. 1996, Skinner and Chang 1996, Skinner and Stephens 2004). However, in the subalpine zone where high-elevation five-needle pines grow, the impact of fire exclusion is thought to be minimal. Subalpine forests are open stands with compact discontinuous fuel loads and natural intervals between fires are quite long (van

[2] The presence of aecial blisters was required for a positive confirmation of rust as part of the field data collection protocol. Non-aecial rust symptoms in the plots were considered to be unconfirmed rust.

Wagtendonk and Fites-Kaufman 2006). In the upper montane zones, high-elevation forests with five-needle pines, such as western white pine, are found in denser mixed-species stands. Fire intervals seem to be shorter or regimes more variable across the Sierra and Klamath mountains (Skinner et al. 2006, van Wagtendonk and Fites-Kaufman 2006). Yet, recent long fire-free time periods have been described for areas of the upper montane Sierra and the mid to upper montane Klamath mountains (McKelvey et al. 1996, Skinner and Chang 1996, Skinner et al. 2006). Stand densities of white and red fir-dominated forests have increased in the Klamath and southern Cascades since fire exclusion (Skinner et al. 2006, Skinner and Taylor 2006). To our knowledge, an understanding of the natural fire cycles coupled with fire exclusion is not clear for the upper montane forests.

Climate change is another key factor influencing forest dynamics over decades, centuries, and millennia (Millar 2004). In California, temperatures are projected to increase from 2 to 6°C from the year 2000 to 2100 (Cayan et al. 2006). Warmer temperatures may result in elevation shifts of California's high-elevation five-needle pines. Species may respond by shifting to cooler sites, such as moving latitudinally, while other species disperse up the mountains. Warmer temperatures may also enlarge the area of mountain pine beetle activity from the current lower elevations (Logan and Powell 2001). The dynamics of forest communities in relation to climate change are not simple however. Climate continues to oscillate at multiple time scales while impacting the ecological traits of each species. These interactions may lead to species assemblages that change, disappear, or expand over time (Millar and Brubaker 2006).

## Practical Issues for Future Management

In considering the future management of high-elevation five-needle pines and their ecosystems, several practical issues were addressed in the presentation:

1) **What's the problem?** The high-elevation pine ecosystems in California have multiple threats, including the native mountain pine beetle, the introduced blister rust, climate change, and other stressors. These high-elevation species also occupy harsh environments and/or are at the margins of their ranges in California, making them more susceptible to the abiotic and biotic stress factors.

2) **Should we be concerned about high-elevation pines in California?** Yes, although mortality was low in the plots, the data revealed low to moderate rust infection with large plot-to-plot variation and some mountain pine beetle incidence. Biotic and abiotic stressors will likely lead to more changes in the future. We need to follow through with monitoring in the plots to examine the effects. At this time, we can certainly raise the awareness of the impacts that are occurring elsewhere and the level of severity that could potentially occur in California.

   The great majority of California's population is closely tied to the urban environment, and seldom, if ever, becomes aware of non-urban problems, much less about what is happening in often inaccessible high-elevation sites. Decline of high-elevation ecosystems is different from a situation like Sudden Oak Death (caused by *Phytophthora ramorum*), where the public can see and is directly affected by dying trees and the resulting fire hazard. This public awareness and concern led to strong political support. Thus, efforts to increase public awareness are valuable for initial and long-term support on conservation and restoration of high-elevation pine ecosystems.

3) **Will management constraints in high-elevation ecosystems limit effective options?** Most high-elevation pine stands in California are in national parks or wilderness, areas that have constraints on management options and degree of intervention. However, active management intervention may be necessary to maintain the natural character of high-elevation pine ecosystems in the face of the exotic white pine blister rust. Managers have different viewpoints on the extent of management that is appropriate. In some situations, restoration of ecosystems is encouraged, but active management to prevent their decline is not. Because multiple factors will influence a decline of high-elevation pines, an interdisciplinary approach will be necessary to develop effective management options. Historically, multi-disciplinary efforts on managing a problem have not always been successful, but early recognition of the complexity of threats may promote information sharing and the development of integrative conservation strategies.

4) **Where's the funding?** Who should be paying to provide management and protection of our high-elevation ecosystems, or paying for genetic conservation efforts? Lack of funding has limited implementation of conservation strategies for high-elevation pine ecosystems in California. Funding for the latest rust survey in California provided general information on the current range and levels of blister rust, and there has been some limited seed banking. However, screening for natural rust resistance of high-elevation pines is not operational and testing remains mainly with research. Financial resources are limited for such work.

5) **Who is going to do the work?** Assuming that sufficient funds were available to do the work necessary to maintain and restore high-elevation ecosystems, are there researchers and managers available to do the work? If so, would the work be done separately by Region or merged among Regions; similarly, would this effort be an inter-Agency effort? These concerns are not unique to California or to high-elevation pine ecosystems.

In summary, California has begun to gather information about the impact of blister rust on the high-elevation five-needle pines. Certainly, more information would lead to a better understanding about the other biotic and abiotic factors affecting these pines and the associated ecosystems. Such information would provide a foundation for developing future conservation and management strategies of these ecosystems. An effort towards developing such strategies will depend on the public interest, and availability of multi-disciplinary personnel and financial resources.

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